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Shahohian et al.

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(45) **Date of Patent: Aug. 18, 2015**

(54) **SPARK GAP FOR HIGH-SPEED CABLE CONNECTORS**

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(51) **Int. Cl.**

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H01R 13/66	(2006.01)

(52) **U.S. Cl.**

CPC ***H01R 13/6485*** (2013.01); ***H01R 13/6658*** (2013.01)

(58) **Field of Classification Search**

CPC H01T 4/06; H01T 4/08; H01T 4/10; H01R 13/6485; H01R 13/6658
USPC 361/119
See application file for complete search history.

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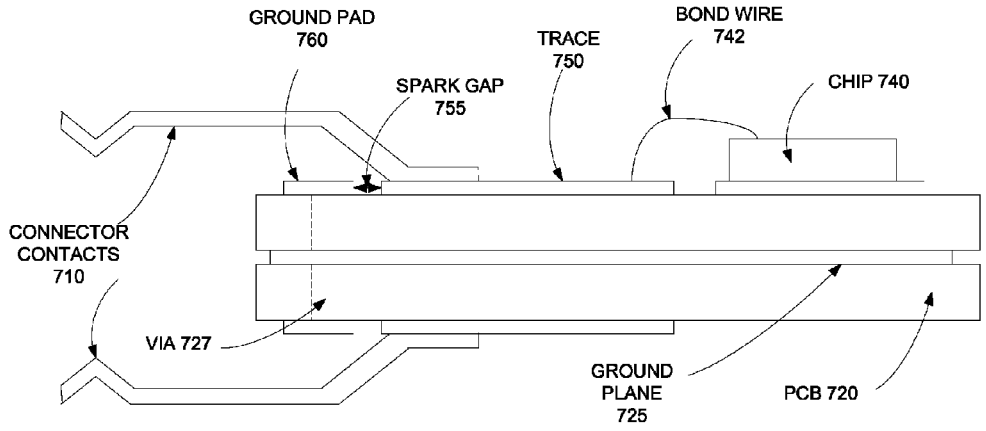
(57) **ABSTRACT**

Circuits, methods, and apparatus that may provide low-capacitance protection from electrostatic discharges. One example protects a circuit in a cable connector that is connected to cable connector contacts. This example may include a number of spark gaps that may be used for electrostatic discharge protection. These spark gaps may be formed using traces a printed circuit board. Signal traces to be protected may be routed such that they pass in close proximity to a ground pad, line, plane, area, or connection. When excessive electrostatic energy builds up on the signal trace, the energy may spark across a gap from the signal trace to the ground pad. The gap and parts of the signal traces and ground may be uncovered such that the electrostatic discharge may dissipate through the air.

23 Claims, 5 Drawing Sheets



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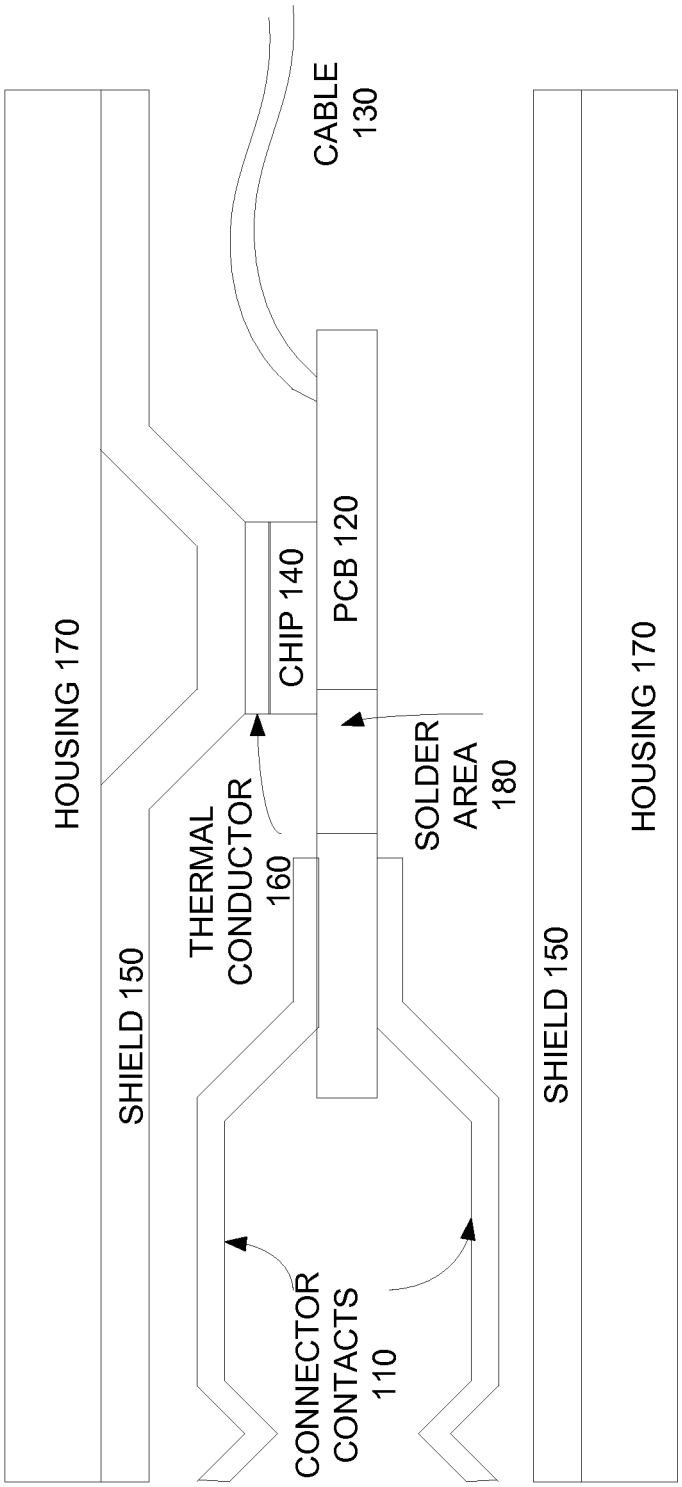
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FIGURE 1

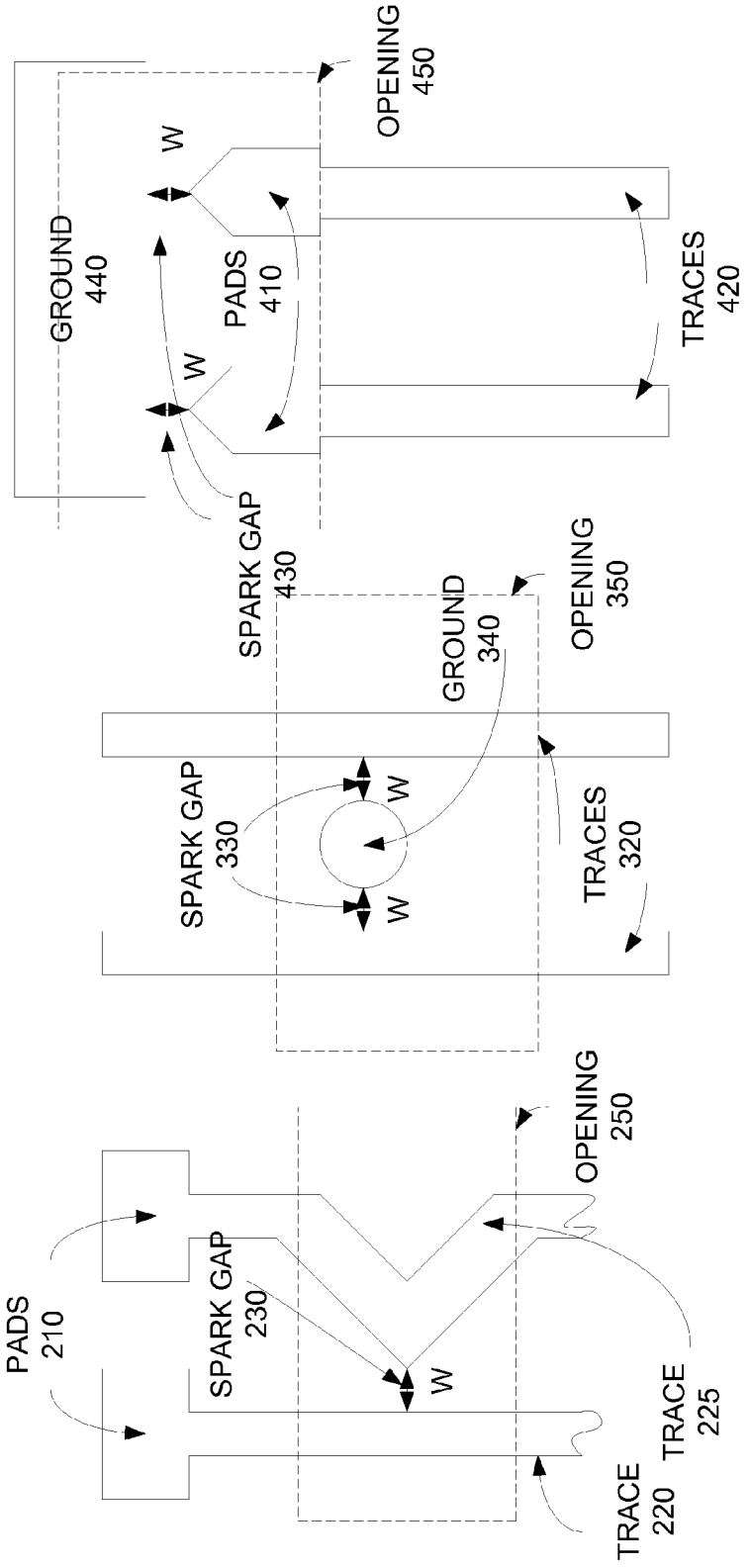
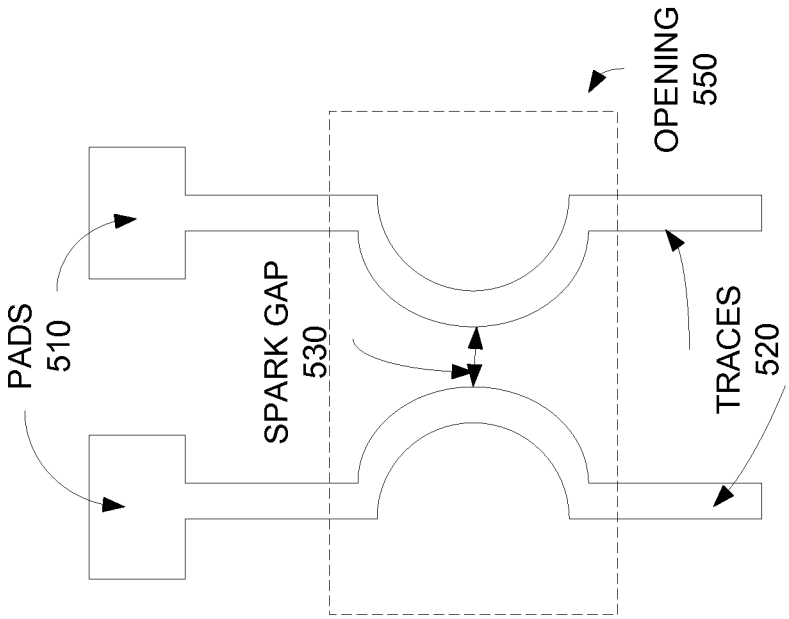


FIGURE 4

FIGURE 3

FIGURE 2



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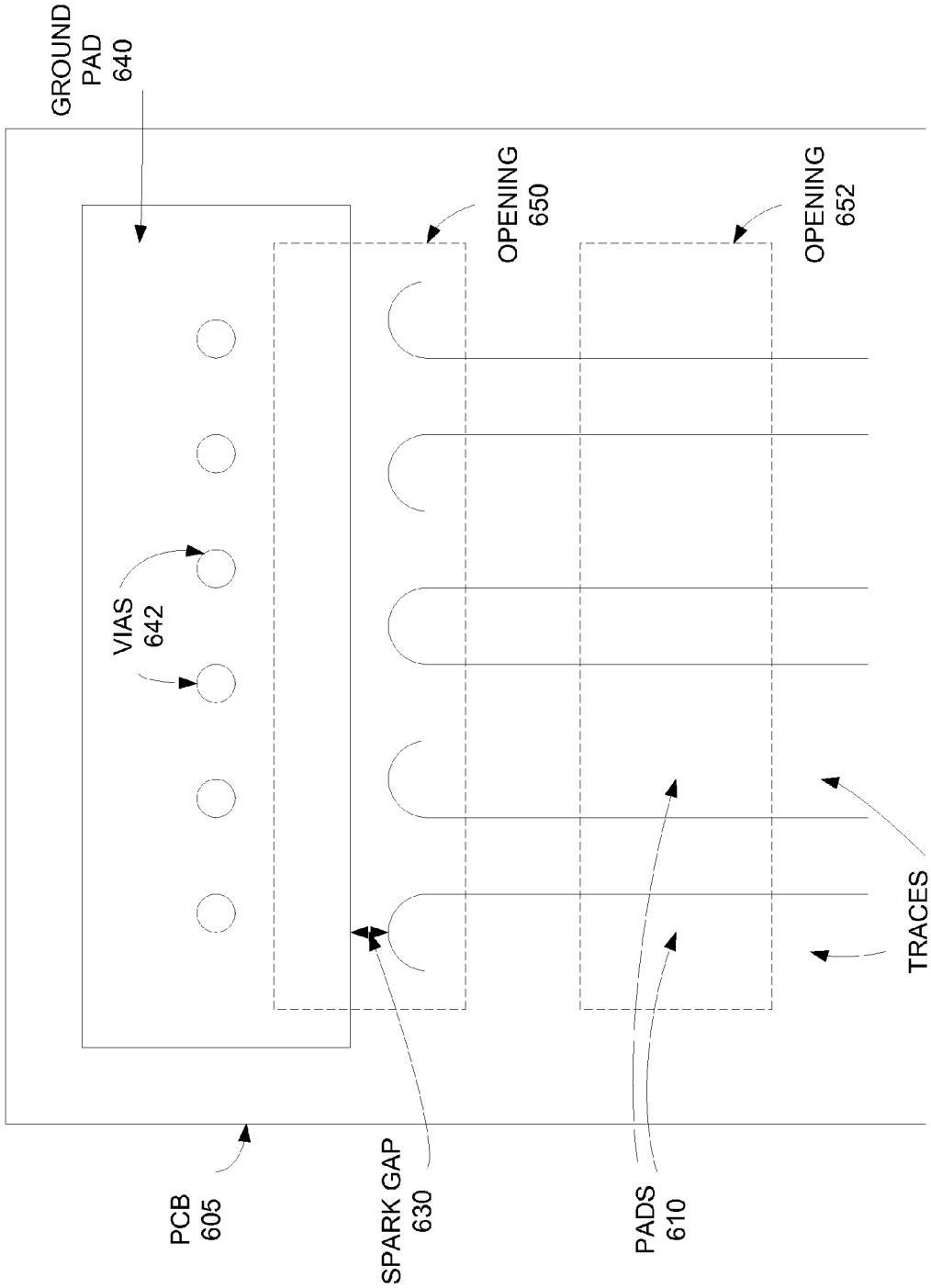
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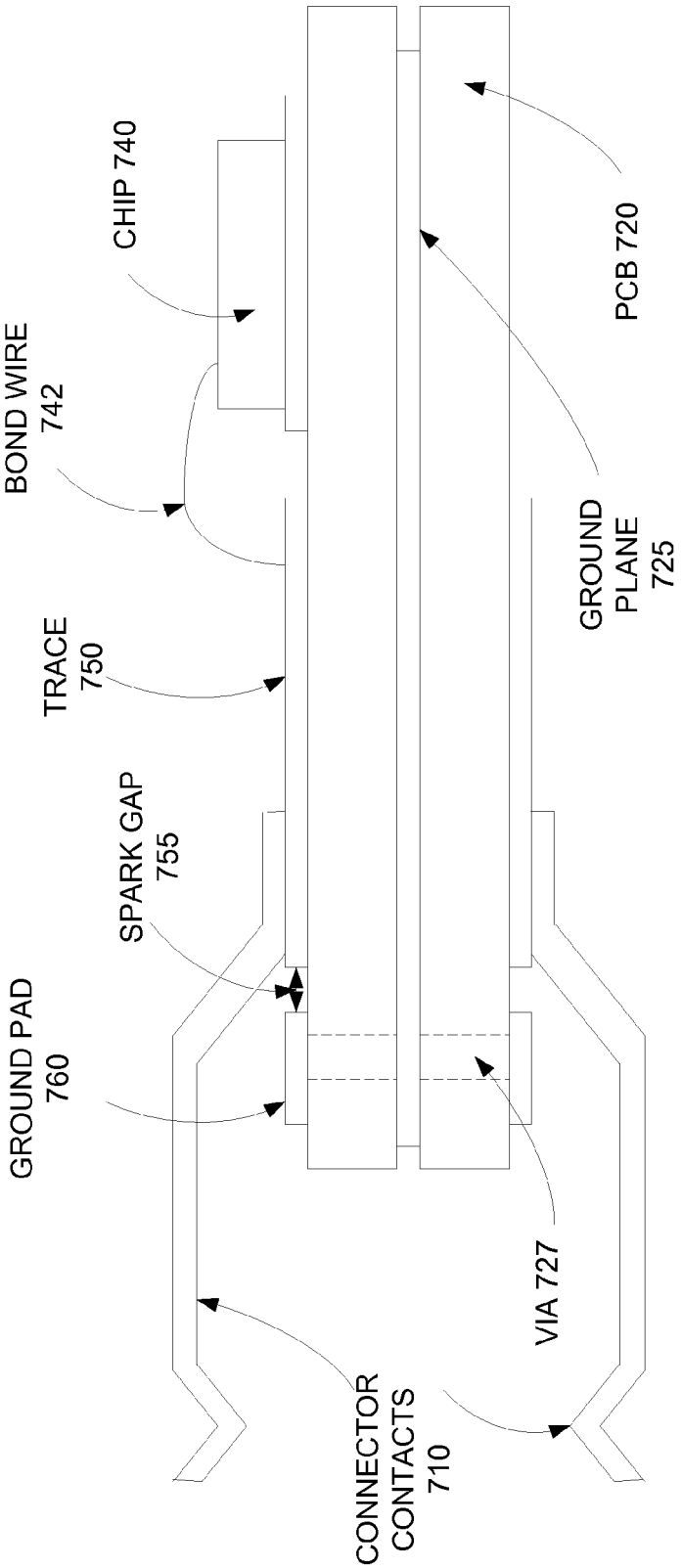
FIGURE 6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PCB 720
BOND WIRE 742
GROUND PLANE 725
TRACE 750
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GROUND PAD 760
VIA 727
CONNECTOR CONTACTS 710

FIGURE 7

SPARK GAP FOR HIGH-SPEED CABLE CONNECTORS

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S. provisional application Nos. 61/408,042, filed on Oct. 29, 2010, titled "Spark Gap for High-Speed Cable Connectors," and 61/360,436, filed on Jun. 30, 2010, titled "HSIO Cable Deskew," which are incorporated by reference.

BACKGROUND OF THE INVENTION

The amount of data transferred between electronic devices has grown tremendously the last few years. Large amounts of audio, video, text, and other types of data content are now regularly transferred among computers, media devices, such as handheld media devices, displays, storage devices, and other types of electronic devices. Since it is often desirable to transfer this data rapidly, the data rates of these data transfers have substantially increased.

Transferring data at these rates has proven to require a new type of cable. Conventional, passive cables create excessive skew between high-speed signals and generate large amounts of electromagnetic emissions that degrade signal quality. Because of this, active cables are being developed to support the high data rates among these electronic devices. These active cables may include electronic circuits that receive, retime, and retransmit data to and from a far end of the cable. These circuits receive and provide signals on connector contacts, which are typically located in connector inserts at each end of the cable.

But these high speed cables are susceptible to damage. For example, static charge can build up on a user of these cables. The user may touch one or more contacts at a cable's connector. This in turn may cause a discharge of the static that has built up on the user, resulting in a transfer of charge from the user to the connector contact. This discharge of static is commonly referred to as electrostatic discharge (ESD). Without proper protection, this discharge can cause excessive voltages to appear at the electronic circuits located in these new, high-speed cables.

Traditionally, ESD protection involves the use of diodes or other junctions that conduct the discharge current safely to ground. Unfortunately, these diodes and other junctions add capacitance to the signal lines that are being protected. These capacitances slow signal edges and degrade high-speed performance.

Thus, what is needed are circuits, methods, apparatus, and other structures that can provide low-capacitance protection from electrostatic discharges at cable connector contacts, as well as other applications.

SUMMARY

Accordingly, embodiments of the present invention provide circuits, methods, apparatus, and other structures that can provide low-capacitance protection from electrostatic discharges. While embodiments of the present invention are particularly suited to use in protecting circuitry connected to cable connector contacts, they may be used in other applications as well.

An exemplary embodiment of the present invention may include a plurality of spark gaps that may be used for electrostatic discharge protection. These spark gaps may be formed using traces on printed circuit boards or other appropriate substrates in the cable connectors. Signal traces to be protected may be routed such that they pass in close proximity to a ground pad, line, plane, area, connection, or other appropriate structure, which is referred to here as a ground pad for simplicity. When excessive electrostatic energy builds up on the signal trace, the energy may spark across a gap from the signal trace to a ground pad. The gap and parts of the signal traces and ground may be uncovered such that the electrostatic discharge may dissipate through the air.

One exemplary embodiment of the present invention provides a connector insert. This connector insert may include a printed circuit board. The printed circuit board may be a multilayer board having a ground plane. The printed circuit board may also have a number of traces printed on one or more outside surfaces, where one or more of these traces are in proximity to a ground pad. The ground pad may connect to the ground plane through one or more vias. Spark gaps may be formed between the one or more traces and the ground pad. A portion of one or more of the traces near the ground pad may be rounded, or it may have another type of shape. A protective covering may cover the printed circuit board. The protective cover may be formed using plastic or other appropriate material. The protective covering may have a first opening over portions of one or more traces, one or more of the corresponding spark gaps, and the ground pad.

This exemplary embodiment of the present invention may further include an integrated circuit located on the printed circuit board. The integrated circuit may include a clock and data recovery circuit. The integrated circuit may be coupled to one or more of the traces. A number of connector contacts may attach to the printed circuit board. The protective covering may have a second opening to allow one or more of the connector contacts to attach to one or more of the traces on the printed circuit board. The printed circuit board may include one or more other traces that attach to conductors of a cable.

Various embodiments of the present invention may incorporate one or more of these and the other features described herein. A better understanding of the nature and advantages of the present invention may be gained by reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a connector insert according to an embodiment of the present invention;

FIG. **2** illustrates the layout of a spark gap according to an embodiment of the present invention;

FIG. **3** illustrates the layout of a spark gap according to another embodiment of the present invention;

FIG. **4** illustrates the layout of a spark gap according to another embodiment of the present invention;

FIG. **5** illustrates the layout of another spark gap according to an embodiment of the present invention;

FIG. **6** illustrates the layout of a portion of a printed circuit board including a number of traces and a ground pad forming a number of spark gaps according to an embodiment of the present invention; and

FIG. **7** illustrates a side view of a portion of a connector insert according to embodiment of the present invention.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

FIG. **1** illustrates a connector insert or connector plug according to an embodiment of the present invention. This figure, as with the other included figures, is shown for illus-

trative purposes and does not limit either the possible embodiments of the present invention or the claims.

This connector insert may be part of an active cable for high-speed data communications. This connector insert may also be part of a docking station or other electronic device or connection to another electronic device. This connector insert may include connector contacts **110**, which may mate with connector contacts of a connector receptacle (not shown). Connector contacts **110** may mechanically attach to printed circuit board **120**. These connector contacts **110** may electrically connect to chip **140** using traces on printed circuit board **120**. Connector contacts **110** and chip **140** may connect to wires and cable **130** via traces on printed circuit board **120**.

A thermal conductor layer **160** may be used to provide a thermal path from chip **140** to shield **150**. A solder area **180**, which may be on the side or top of printed circuit board **120**, may be soldered to a portion of shield **150**, thereby creating a low thermal resistance path for heat dissipation. Housing **170** may be used to surround shield **150**.

Again, circuitry in these connector inserts, such as chip **140**, may need to be protected from ESD. Typically, ESD protection is connected to signal traces in the connector insert that are connected to chip **140**. Unfortunately, conventional electrostatic discharge protection relies on diodes or junctions, which create excessive capacitance on signal traces that slow edges and thereby degrade cable performance. Accordingly, embodiments of the present invention do not rely on diodes or junctions, but instead include a spark gap. Examples of spark gaps according to embodiments of the present invention are shown in the following figures.

FIG. **2** illustrates the layout of a spark gap according to an embodiment of the present invention. In this example, two traces, trace **220** and trace **225**, may be configured such that they approach each other a distance "W" at spark gap **230**. Cable wires or insert connectors may attach to pads **210**. Conventionally, one trace may be ground, while the other trace may be a signal path. As electrostatic builds up between these two traces **220** and **225**, a discharge across spark gap **230** may dissipate the energy. An opening **250** may be included such that the spark may cross through the air from one trace to another.

FIG. **3** illustrates the layout of the spark gap according to another embodiment of the present invention. In this example, two traces **320** may be used to protect circuitry by including spark gaps **330** to ground path **340**. Again, an opening **350** may be included such that a spark may be dissipated through the air.

FIG. **4** illustrates the layout of a spark gap according to another embodiment of the present invention. In this example, pads **410** may couple to traces **420** and may further attach to cable wires or insert connectors. A spark gap **430** to ground **440** may be included for each pad **410**. Again, an opening **450** may be included.

FIG. **5** illustrates the layout of another spark gap according to an embodiment of the present invention. In this example, pads **510** may couple to traces **520**, which may curve near each other, thereby forming spark gap **530**. Again, an opening **550** may be included.

FIG. **6** illustrates a top view of a portion of a printed circuit board **605** according to an embodiment of the present invention. Printed circuit board **605** may reside in a connector insert, such as the connector insert shown in FIG. **1**. A number of traces **620** may be located on printed circuit board **605**. Ground pad **640** may also be included on printed circuit board **605**. Traces **620** may have rounded edges that face ground pad **640**. The rounded portions of traces **620** and ground pad **640** may form spark gaps **630**.

A protective coating may cover portions of printed circuit board **605**. This protective coating may include opening **650**. Opening **650** may provide an opening in a coating that covers printed circuit board **605**. Again, this coating may be plastic or other material. Opening **650** may provide an opening over a portion of traces **620**, ground pad **640**, and spark gaps **630**. A second opening **652** may be included over a portion of traces **620** away from ground pad **640**. These openings may form pads **610**. Pads **610** may be used to connect traces **620** to connector contacts (not shown).

Ground pad **640** may connect to a ground plane (not shown), which is typically embedded in printed circuit board **605**. In this example, this connection may be made using vias **642**.

This structure may provide electrostatic discharge protection for high-speed cable inserts as well as for other applications. This protection may be achieved without incurring excessive capacitance on traces **620**. This protection may also be achieved at an extremely low cost, the cost being primarily printed circuit board area for ground pad **640**, and manufacturing costs associated with vias **642**.

If a user touches a connector contact (not shown) such that an electrostatic discharge occurs, charge may be transferred via the connector contact to a pad **610**. This charge may then flow through a trace **620** and jump across spark gap **630**, where it is dissipated to ground via ground pad **640**.

Again, spark gaps **630** may be used in a number of applications. One particular application is a connector insert, such as the connector insert shown in FIG. **1**. A more detailed view of the connector insert of FIG. **1** is shown below.

FIG. **7** illustrates a side view of a portion of a connector insert or connector plug according to embodiment of the present invention. This example illustrates a printed circuit board **720**. Printed circuit board **720** may be a multilayer printed circuit board. Printed circuit board **720** may include a ground plane **725**. This ground plane **725** may be formed of a layer of metal or other conducting material between two layers of the printed circuit board **720**. Ground plane **725** may connect to ground pad **760** using vias **727**.

Traces **750** may be included on printed circuit board **720**. Spark gap **755** may be formed between traces **750** and ground pad **760**. Connector contacts **710** may contact one or more traces **750**. An integrated circuit **740** may be located on printed circuit board **720**. Integrated circuit **740** may connect to one or more traces **750** using bond wires **742**.

With this configuration, spark gap **755** protects integrated circuit **740** from electrostatic discharges that reach connector contacts **710**. Specifically, charges that reach connector contacts **710** flow to traces **750**. From there, they can jump spark gap **755** to reach ground pad **760**. Once at ground pad **760**, the charge dissipates to ground through the vias **727** and ground plane **725**. This prevents much of the charge from reaching bond wire **742** and integrated circuit **740**. In other embodiments of the present invention, other traces, such as traces coupled to a cable, may be protected from electrostatic discharge.

The above description of embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form described, and many modifications and variations are possible in light of the teaching above. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

Thus, it will be appreciated that the invention is intended to cover all modifications and equivalents within the scope of the following claims.

What is claimed is:

1. A connector insert comprising:
- a printed circuit board;
- a plurality of first traces located on a top side of the printed circuit board;
- a plurality of first connector contacts, each first connector contact attached to one of the plurality of first traces and having connector contact portions above the printed circuit board;
- an integrated circuit coupled to at least a first trace in the plurality of first traces, wherein a first length of the first trace extends from a first connector contact to the integrated circuit;
- a first ground pad located on the top side of the printed circuit board such that a plurality of first spark gaps are formed under the connector contact portions of the plurality of first connector contacts, each first spark gap formed between a trace in the plurality of first traces and the first ground pad, wherein a second length of the first trace extends from the first connector contact to a corresponding first spark gap; and
- a protective covering over the printed circuit board, the protective covering having a first opening over at least a first portion of the second length of the first trace, a portion of the first ground pad, and the corresponding first spark gap.

2. The connector insert of claim **1** wherein the printed circuit board is a multilayer board and comprises a ground plane, and wherein the connector insert further comprises:
- a plurality of second traces on a bottom side of the printed circuit board;
- a plurality of second connector contacts, each second connector contact coupled to one of the plurality of second traces and having connector contact portions below the printed circuit board; and
- a second ground pad located on the bottom side of the printed circuit board such that a plurality of second spark gaps are formed above the connector contact portions of the plurality of first connector contacts, each second spark gap formed between a trace in the plurality of second traces and the second ground pad.

3. The connector insert of claim **2** wherein the first ground pad and the second ground pad are coupled to the ground plane using a plurality of vias.

4. The connector insert of claim **1** wherein the first trace has a first rounded end.

5. The connector insert of claim **4** wherein the first rounded edge faces the first ground pad to form the corresponding first spark gap.

6. The connector insert of claim **1** wherein the first trace is configured to convey a signal.

7. The connector insert of claim **1** wherein the connector contacts are arranged to mate with connector contacts in a connector receptacle.

8. The connector insert of claim **1** wherein the integrated circuit comprises a clock and data recovery circuit.

9. The connector insert of claim **1** wherein the protective covering comprises plastic.

10. The connector insert of claim **1** wherein the protective covering further comprises a second opening, the second opening at least over a second portion of the first trace to allow contact by one of the plurality of connector contacts.

11. A cable assembly comprising:
- a cable comprising a plurality of conductors and having two ends; and
- two connector inserts, one connector insert on each end of the cable, wherein each connector insert comprises:
  - a printed circuit board;
  - a plurality of first traces on a top side of the printed circuit board;
  - a plurality of second traces on the printed circuit board, each coupled to a conductor in the cable;
  - a plurality of first connector contacts, each first connector contact coupled to one of the plurality of first traces and having connector contact portions above the printed circuit board;
  - an integrated circuit coupled to at least a first trace in the plurality of first traces, wherein a first length of the first trace extends from a first connector contact to the integrated circuit;
  - a first ground pad located on the top side of the printed circuit board such that a plurality of first spark gaps are formed under the connector contact portions of the plurality of first connector contacts, each first spark gap formed between a trace in the plurality of first traces and the first ground pad, wherein a second length of the first trace extends from the first connector contact to a corresponding first spark gap; and
  - a protective covering over the printed circuit board, the protective covering having a first opening over at least a first portion of the second length of the first trace, a portion of the first ground pad, and the corresponding first spark gap.

12. The cable assembly of claim **11** wherein the plurality of conductors comprises a pair of conductors to carry a high-speed differential signal.

13. The cable assembly of claim **11** wherein the plurality of conductors comprises a conductor to carry a high-speed single-ended signal.

14. The cable assembly of claim **11** wherein each connector insert further comprises:
- a plurality of third traces on a bottom side of the printed circuit board; a plurality of second connector contacts, each second connector contact coupled to one of the plurality of third traces and having connector contact portions below the printed circuit board; and
- a second ground pad located on the bottom side of the primed circuit board such that a plurality of second spark gaps are formed above the connector contact portions of the plurality of first connector contacts, each second spark gap formed between a trace in the plurality of third traces and the second ground pad.

15. The cable assembly of claim **14** wherein the second plurality of traces are located on a first side of the printed circuit board.

16. A connector insert comprising:
- a printed circuit board;
- a plurality of first traces located on a top side of the printed circuit board;
- a plurality of first connector contacts, each first connector contact contacting one of the plurality of first traces and having connector contact portions above the printed circuit board;
- a plurality of second traces located on the printed circuit board, the plurality of second traces for coupling to conductors of a cable;

an integrated circuit coupled to at least a first trace in the plurality of first traces, wherein a first length of the first trace extends from a first connector contact to the integrated circuit;

a first ground pad located on the top side of the printed circuit board such that a plurality of first spark gaps are formed under the connector contact portions of the plurality of first connector contacts, each first spark gap formed between a trace in the first plurality of first traces and the first ground pad, wherein a second length of the first trace extends from the first connector contact to a corresponding first spark gap; and

a protective covering over the printed circuit board, the protective covering having a first opening over at least a first portion of the first trace, a portion of the first ground pad, and the corresponding first spark gap.

17. The connector insert of claim **16** wherein the protective covering further comprises a second opening for allowing one of the connector contacts to contact one of the first plurality of traces.

18. The connector insert of claim **16** wherein the integrated circuit comprises a clock and data recovery circuit.

19. The connector insert of claim **16** further comprising:

a plurality of third traces on a bottom side of the printed circuit board;

a plurality of second connector contacts, each second connector contact coupled to one of the plurality of third traces and having connector contact portions below the printed circuit board; and

a second ground pad located on the bottom side of the printed circuit board such that a plurality of second spark gaps are formed above the connector contact portions of the plurality of first connector contacts, each second spark gap formed between a trace in the plurality of third traces and the second ground pad.

20. The connector insert of claim **16** wherein the printed circuit board comprises a ground plane and wherein the ground plane couples to the ground pad using a plurality of vias.

21. The connector insert of claim **1** wherein a first length of the first trace extends in a first direction from a first connector contact to the integrated circuit a second length of the first trace extends in a second direction from the first connector contact to a corresponding spark gap, the second direction opposite the first direction.

22. The cable assembly of claim **11** wherein a first length of the first trace extends in a first direction from a first connector contact to the integrated circuit a second length of the first trace extends in a second direction from the first connector contact to a corresponding spark gap, the second direction opposite the first direction.

23. The connector insert of claim **16** wherein a first length of the first trace extends in a first direction from a first connector contact to the integrated circuit a second length of the first trace extends in a second direction from the first connector contact to a corresponding spark gap, the second direction opposite the first direction.

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